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ABSTRACT

Graph theory provides a useful framework for generating insights into problems of sufficiency and optimality across a wide variety of physical relationships. Applied to the realm of grand strategy, this approach assists in developing a methodology for estimating the minimum level of forces required and determining the optimal deployments for the successful pursuit of national security goals. In theory, the adoption of a defense-in-depth maneuver strategy provides the most efficient use of scarce resources. However, deterrence stability attenuates due to the absence of robust local balances of forces. Comparative case analyses of the Roman and British empires confirm the efficiency of depth defense, as well as the weakening of deterrence. Implications for U.S. policy are that, despite sizeable reductions, two regional wars can be fought and won, nearly simultaneously, even below base force levels. However, the deployments required to effect this grand strategy may make challenges to conventional deterrence more likely. Finally, it is demonstrated that small increases in forces above minimum requirements create a valuable "margin of safety" and may significantly improve crisis and deterrence stability.

The specter of decline confronts all great powers eventually. A substantial body of literature, associated generally with theories of either power transition or cycles of relative power, addresses the onset of and efforts to cope with this unavoidable problem (Doran 1971; Organski and Kugler 1980; Gilpin 1981; Kennedy 1987; Modelski 1987; Goldstein 1988). Fundamentally, decline poses a strategic dilemma: that of either trying to maintain the status quo with scarce resources, even by means of preventive war (Gilpin 1981, 191); or by retrenching, unilaterally reducing spheres of influence.[1] Both approaches can entail great risks.

Imperial Spain, for example, faced with declining resources, attempted to hold all of the vast gains it made in the 16th century, and found itself consistently "overstretched," unable to deter predatory attacks, or to defend successfully against them (Elliott 1991). The Soviet Union, on the other hand, recognized its material deficiencies, and chose, a few years ago, to retrench preemptively, resulting not only in the swift breakup of its imperium, but also in the substantial dissolution of its own polity.

Of the two strategic approaches, "holding the line" appears less risky at the margin, perhaps because the effects of decline may be mitigated by spreading them over a longer period of time. The Spanish empire took nearly 300 years to collapse, from the loss of Holland in 1609 to the war with the United States in 1898. The Ottoman empire followed a similar temporal pattern of senescence. The former Soviet Union, which instead chose retreat, is absorbing the substantial, wrenching consequences of imperial loss over an extremely short period. Even Britain, which withdrew skillfully from empire in the wake of the Second World War, suffered some of the immediate economic and politico-military consequences of strategic retreat, though they were cushioned by the willingness of the United States to fill the British void.

Because of the seemingly high risks of retreat, even of partial withdrawal, this study concentrates its analysis on the stodgier option, maintaining the status quo, and upon the implications, for deterrence and defense, of adopting a grand strategy of "holding the line." It introduces first a mathematical graphing methodology by means of which optimal choices for using scarce resources may be identified. Previous efforts along these lines have employed insights from geometry to develop a framework for successful defense at the tactical and operational levels (Gupta 1993). This study focuses upon the grand strategic level of analysis, and considers the prevention of war as well as defense against aggression. With regard to successful deterrence, special attention is given to the perceived need to achieve favorable immediate or short-term local balances of forces (Huth and Russett 1984, 1988; Huth 1988).

This new methodological approach to optimizing security strategies is then applied retrospectively to the two most notable historical cases of great empires, one primarily continental, the other maritime, as they confronted potential decline: Rome in the 4th century and Britain before World War I. Insights drawn from these studies will then be applied to help analyze the current situation of the United States in the post-Cold War world, with special emphasis given to the propriety of the current

American strategy of attempting to fight and win two regional wars nearly simultaneously.

OF GRAPHS AND "PEBBLES"

More than any other formal analytic framework, graphical analysis has long been effectively used to model a wide variety of physical relationships (Kemeny and Snell 1962), from the feeding habits of rainforest animals (Harrison 1962) and the optimization of municipal services (Tucker 1973), to the most efficient means for assigning radio frequencies (Hale 1980).

This study views regions of the globe as nodes on a graph. An edge between nodes indicates their proximate relationship. Two nodes are adjacent if they are incident on the same edge; and any two nodes that are not adjacent are called separated. The distance between adjacent nodes is exactly 1. The distance between separated nodes is equal to the number of edges between adjacent nodes on the shortest path that connects them.

Further, "pebbles," notional representations of the minimum forces needed in order to control a node, are introduced and placed on the nodes of the graph. The pebbles may be moved from node to node along edges. Such moves on the graph are reminiscent of, and have their basis in, classical games such as Awari, an offshoot of the Mankale'h family of games, including backgammon. In these ancient games, pebbles on a node may be swept up and distributed among adjacent nodes by means of movement along incident edges.

In this game, a pebble can move from one node to another; however, a cost of "1" is assessed for each pebble moved. Additionally, no pebble may move if it is the last pebble remaining at the node. With regard to lengthier moves, first k-1 pebbles are moved to an adjacent node along the path to the terminal node. The cost of this initial move is k-1, as there were k-1 pebbles moved along the first edge. Then k-2 pebbles are moved along the second edge, k-1 along the third edge, etc.; until, finally, the last pebble is moved along the k-1st edge to the terminal node. The resulting structure is a string of k adjacent nodes, each of which possesses exactly 1 pebble and is connected by edges. This forms a "bridge" of length k. The cost to build the bridge is the total cost of all of these moves. Cost is given as:

Eq. 1: (*Cost Determination*)

$$1+2+3+...+k-1 = k(k-1)/2$$

The goal in moving pebbles is to place one at any prescribed node from a given initial configuration. If this can be accomplished, the original deployment of pebbles achieves the sufficient condition to qualify as a winning situation. Each pebble, therefore, represents a force able to seize, hold and control the territory represented by the nodes. Thus, a single pebble comprises all that is necessary, to a high degree of probability, to win a regional conflict at that location.[2] It is assumed, for analytic purposes, that the composition of pebbles does not include allied forces. Contingency and military requirements planning must consider the possibility that a nation will have to fight alone on occasion, or that allies might prove either inconstant or ineffective.

The bridge that is built to produce a win is consistent with notions of the strategic importance, and costs, of secure lines of communication, and has analogs in history. The closest parallel, no doubt, may be seen in the island-hopping strategy employed by the United States in the Pacific War against Japan (1941-1945), wherein "bridges" were built from one staging point to the next, with each providing security for the advance of further forces. Even in the recent Gulf War, where the Mediterranean was simply used for transit, significant forces had to be employed to keep the "bridge" secure at all times (Owens 1995, 80).

The more distant the target node, the greater the cost of reaching it in terms of time and resources expended. In this model, no further costs, such as placing a cost label on edges between nodes, or intra-nodal movement, are assessed. Even so, the costs of bridge-building are substantial. However the existence of the bridge has great importance in terms of developing the capability for reconcentration of forces to meet a second conflict that arises even while the first is in progress, a scenario envisioned by the current U.S. warfighting doctrine of retaining the ability to fight two regional wars with near simultaneity. The costs described herein reflect reasonably the concept of the loss-of- strength gradient (LSG) described by Boulding (1962).[3] Simply put, this formulation holds that the projection of power entails predictable costs that increase, in the aggregate, with distance.

The initial placement of pebbles can be crucial to producing a win without incurring unreasonable costs due to having a large number of required moves. Further, this study assumes that deterrence of aggression at any specific node can be achieved by an initial placement of pebbles that allows a win at less than a cost of 2; that is, if there is a pebble on the node in question, or if one may be deployed there at a cost of 1. This captures the theoretical notion that deterrence success depends heavily upon the immediate and short-term local balance of forces in a crisis (Huth and Russett 1984, 1988; Huth 1988). It also recognizes that, while bridge-building may provide, ultimately, an adequate form of defense, it nevertheless may not deter well in those cases where response times are slowed by distance factors.

These distance factors imply a need to distinguish between "simple" and "complex" graphs. The former possess a node adjacent to all others, the latter do not. Further, there are levels of complexity, measured in terms of the number of nodes at a distance of "2" from any given node. The key point introduced by this concept is that complex graphs contain the eventual, but inevitable need for bridge building. Thus, complexity entails varying costs for alternate initial deployment schemes, which can differ radically. In particular, when the need arises for movement to control a second key node, graph complexity greatly complicates optimality calculations. One means for dealing with complexity when contemplating initial deployments, we hypothesize, is to break down complex graphs into simple components, assuming that this approach will encourage deployments designed to minimize the costs of graph coverage.

Current U.S. defense strategy, for example, calls for placement of sufficient force to allow for winning two regional wars nearly simultaneously (Aspin 1993). In this instance, sufficient pebbles must be initially placed so that a win can be achieved at any given location, followed by a win at any second location. Note that pebbles moved to produce the first win at the location of the initial conflict cannot typically be moved, as they will now be single pebbles incapable of movement on their own. However, these pebbles do provide a bridge along which any individual pebble may travel. In this case, the cost of using the established bridge is just 1 for each step along the way. Then, the cost of the original configuration is computed as the cost to achieve the win-win scenario. This is the worst-case cost for the choice of any ordered pair of nodes involved in the win-win scenario, where the costs of

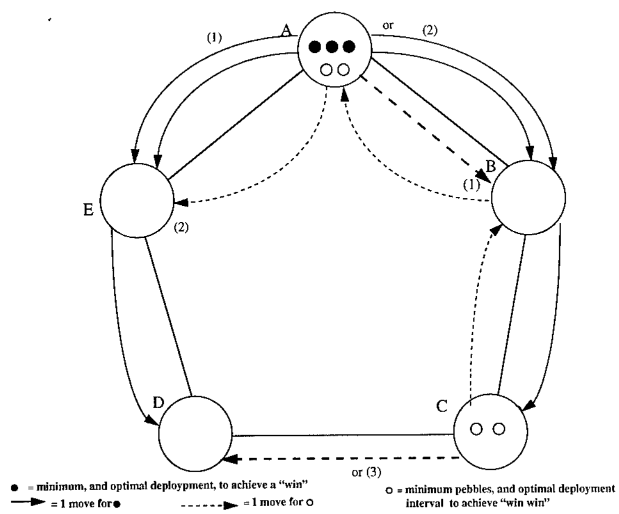

Figure 1. The "Pentagon"

producing the respective wins at the two nodes is minimized by following the shortest possible paths from nodes pebbled in the original configuration.

A THEORETICAL EXAMPLE

To illustrate the concepts and definitions developed above, one may consider the cycle graph on five nodes (C5, see Figure 1). No particular meaning need be associated with the nodes of this pentagonal structure, though they could easily be related to areas of interest to the United States: the Western hemisphere, Europe, the Near East, South Asia and the Far East. The letters A through E are assigned to the five nodes, beginning at the top of the pentagon and proceeding in clockwise order. With regard to the issue of "complexity," the pentagon's is equal to 2, as there are two nodes at distance 2 in the graph for any given node.

From the rules of movement, it should be clear that possession of either one or two pebbles will not allow for achieving even a single "win." Therefore, our illustrative analysis begins with three pebbles. To place three requires, initially, the use of 1, 2, or 3 locations. Though every possible configuration is analyzed herein, one must also remain cognizant of the practical limitations that might develop in reality, as economic constraints (unwillingness to pay host-costs) or political sensivities (such as to having non-Muslim troops permanently stationed on the territory of an Islamic state) may prevent deployment to certain nodes.[4] There is only one way that three pebbles can be assigned to a single node, and two ways that two nodes may be used. These represent the two-fold choice of whether to select nodes that are adjacent or separated. Distractions of the left or right are not considered as being distinct of the two nodes where one gets 2 pebbles and one receives just 1. If three nodes are utilized, there are again just two possibilities, either all contiguous, or one separated from the others.

The latter two cases can be ruled out quickly, and may be illustrated by the 5-tuple configurations (11100) and (11010) respectively. In both cases three nodes are covered with no moves permitted, failing to achieve a win. When two nodes are utilized initially, a single pebble move may be made from the node containing 2 pebbles. This may be depicted as (20100)—>(11100)-1, or (20100)—>(10101)-1. The arrow indicates a move, and the nonparenthetic integer reflects accumulated costs. In total, four different nodes have been covered at a worst case cost of 1. No winning configuration appears. The case of adjacent nodes is illustrated as (21000)—>(11001)-1, or (21000)—>(12000)-1—>(11100)-2. The cost is one for the first move in either case, but a second move is possible at an additional cost of 1. Again, exactly four nodes are covered, now at a worst case cost of 2. Still, no winning configuration emerges from these placements.

Where all 3 pebbles are placed at a single node initially, there are more possibilities. Now, two pebbles can move to an adjacent node, and then a single pebble can be moved further. This is illustrated by (30000)—>(21000)-1 —>(12000)-2—>(11100)-3. Here, the worst-case cost is 3 to cover three nodes. Since the moves may also be made in the counterclockwise direction, the situation may be alternately rendered as (30000)—> (20001)-1—>(10002)-2—> (10011)-3, again covering three nodes at a cost of three. Together, at a worst-case cost of 3, all five of the nodes (A-E) have been covered in one sequence or the other; and a winning configuration is established by virtue of all the nodes being covered via this "depth defense" deployment of the pebbles. (30000) is a winning configuration whose cost = 3.

Though a winning configuration emerges at the 3-pebble level, no "win win" scheme has yet been identified. Therefore, the analysis must proceed to the level of 4 pebbles. In this scenario, only the case of the initial occupation of four nodes (11110) fails to achieve a winning configuration. In all other cases, a win with 4 pebbles is easily established. Costs for each "single win" option are given in Table 1.

There are only two ways, though, to establish a "win win" scenario with an initial placement of 4 pebbles. If all are placed at a single node, then regardless the order in which two nodes are named, it is possible to reach both. Either adjacent node is reached in 1 step: (40000)—>(31000)-1, or —> (30001)-1. Then, either (originally) separated node can be reached utilizing one or the other bridge in two additional steps, for a total cost of 3. If one of these separated nodes were the first named, then it could

Table 1. Winning 4-Pebble Configurations.

COST	CONFIGURATION
1	(20110), (20200)
2	(21010), (21001)
3	(21100), (30100), (31000), (40000)
4	(22000)

be covered in 3 steps: (40000)—>(31000)-1 —>(22000)-2—>(21100)-3. Then, if an originally separated node is named second, it can be reached in three additional steps utilizing an established bridge: (21100)-3—>(12100)-4—> (11200)-5—>(11110)-6. The win-win scenario is thus achieved for this configuration (all pebbles on one node), and the cost for the double win = 6.

The other way to achieve a win-win is by means of the placement (20200). The first chosen node (or conflict) can be reached at a cost of 1 in every case. A second occurrence anywhere may then also be reached, though the cost varies with the location. Cost analysis requires the consideration of two cases. The first named node may be adjacent to just one of the initially occupied nodes, in which case the second node can be reached in just one more step, for a total cost of 2. Alternately, the first named node could be adjacent to both occupied ones. In this instance, referring to Figure 1, one might hypothesize 2 pebbles on A and 2 on C, with a conflict erupting on B. Either choice of how to occupy that node (moving from A or from C) establishes a bridge (20200)—>(21100)-1, to the most distant node, which can now be reached in three additional moves (21100)-1—>(12100)-2—>(11200)-3—> (11110)-4. The worst-case cost to achieve the win-win scenario = 4.

With a minimum number of pebbles needed to achieve a double win of 4, it is interesting to engage in some marginal analysis, to consider the effect, in terms of cost savings, of adding one pebble, for a total of 5. In this case, though, placement on only one or two nodes is considered, reflecting implicitly the political or economic limitations on "overseas" basing that often arises in reality. Given this restriction, only five cases require consideration: (50000), (41000), (40100), (32000) and (30200). Win-win scenarios exist in every case, but the costs are startlingly different. In the respective cases described above, the costs are 6, 5, 4, 4, and 2. Thus, in light of the best deployment of 5 pebbles at two or fewer nodes, *a modest increase in force size may generate cost savings of 50%*. That is, cost computed in terms of the required time to respond effectively to any threat. For deterrence stability, such a finding could have profound implications.

The best-case scenario plays out as (30200)—> (21200)-1, and then the second named node can be covered by one step in either direction, without requiring the use of the bridge. Of course, the costs of increasing force size by one-fourth might generate domestic political resistance, if the only cost saving were a one-half reduction in response time in crisis. On the other hand, if such a marginal increase cut the likelihood of an outbreak of war, or other failure of deterrence, in half, then the gains might well be viewed as greater than the costs.

The foregoing theoretical examples form the basis for the following case studies, which key on force minimization and optimization, for deterrence and defense. The situations faced by Rome and Britain, when their empires were territorially most expansive and their material constraints were beginning to be sharply felt, have been chosen for comparative analysis. It will also be argued that the United States faces a similar situation in the post-Cold War world, with still-extensive commitments and interests coming into tension with economically straitened circumstances.

HISTORICAL CASES

The Pax Romana

At the height of its power in the 3rd century, Rome fielded approximately 50 standing legions, aggregating over 300,000 combat troops, exclusive of auxiliaries (Gibbon [1776]1937; Luttwak 1976; Macmullen 1980; Delbruck [1921]1990). These forces deployed evenly to the many border areas of the imperium, providing Rome with an explicit "forward defense" based on a doctrine of positional warfare. Additionally, their presence at the marches of the empire encouraged friendly barbarians to settle nearby, creating an "external depth" that further enhanced security (Ferrill 1991). Over time, though, the empire stagnated economically, and couldn't maintain the same large military machine that characterized its halcyon days.

Thus, by the 4th century, the Roman armed forces had shrunk nearly in half, from 50 to roughly 25 standing legions (Luttwak 1976, 189). Forward, positional defense grew infeasible. At this point, Constantine instituted quantum changes in Roman grand strategy, going well beyond the "shallow depth" hybrid defensive scheme advanced by Diocletian over a century earlier. Constantine directed the redeployment of the legions, roughly half in the environs of Rome and Northern Italy, the remainder in the vicinity of the city which bears his name. The defense-in-depth maneuver strategy that underlay this shift held that the legions would now be better suited to responding to any emergent threats around the perimeter of the empire (Jones 1964; Luttwak 1976). This approach conceded that some territory would be lost in the initial phase of conflict, but that it would be reconquered expeditiously.

For purposes of graphical analysis, each Roman "pebble" consists of six legions of regular field forces, or *comitatenses*. This figure derives from Gibbon's and Delbruck's accounts of the forces needed for the major campaigns of the 2d-4th century period. Of course, exact numbers of troops remain shrouded in obscurity, but the numbers of legions engaged often emerges with clarity. Again, as in the previous theoretical example, allied forces and barbarian levies, because of their unreliability, so well borne out historically, are not included in the "pebbling" process.

Figure 2 depicts the strategic schematic of the Roman empire at its height, with key nodes set at the two capitals and all perimeter areas. Edges represent, and are in line with, Rome's principal roads and maritime lines of communication. The compexity of this graph is three. Using the six-legion pebbling guideline generates eight pebbles in the 2d century, four in the 4th. Thus, at its greatest strength, the empire could continuously maintain enough forces to win a field campaign on each of its key nodes. The legions were indeed "legion." Two centuries later, though, four pebbles had to cover the same eight nodes. Was the Constantinian depth defense the correct answer for Rome, as Luttwak (1976) has argued? Was it optimal?

Constantinian depth defense may be represented, using Figure 2, by envisioning the placement of two pebbles each on Rome and Constantinople. This configuration does allow for the achievement of a "win." That is, these

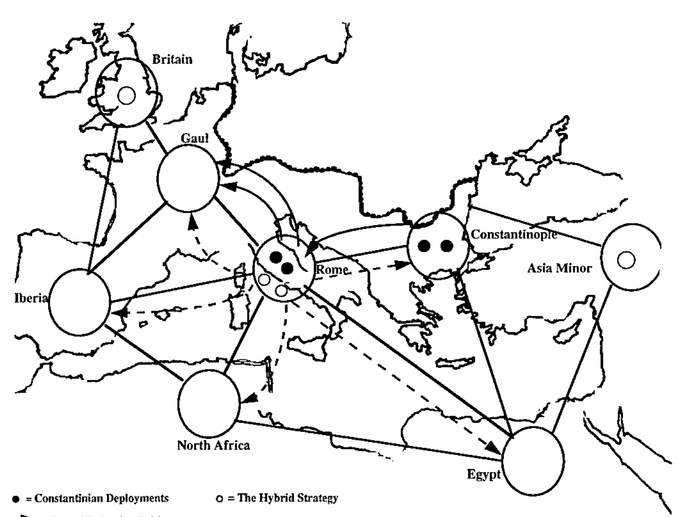

Figure 2. Strategic Schematic of The Roman Empire

forces may deploy to any region in imminent crisis or war. Response time to all locations, save for Britain, is 1 each, implying that deterrence ought to hold in these areas. Reaching Britain, however, entails a cost of 4, as a Rome-Gaul bridge must be established (1) and then a pebble can move from Constantinople-Rome-Gaul-Britain (+3, total cost of 4). If an edge existed between Gaul and Constantinople, the cost of moving to Britain would reduce to 3, but the interposition of the unfriendly, and unconquered Germans made this infeasible.

Thus, the total cost of Constantine's depth defense is 9, and the strategy does not guarantee a "win win" situation either, although Britain is the only node that prevents this. The difficulties and costs of defending Britain had long concerned Roman leadership, leading early on to the creation of Hadrian's Wall, the Maginot Line of its day. Presumably, this fortification acted as a deterrent and force multiplier, freeing up the legionary field forces for the defense of the rest of the imperium. Interestingly, there are a variety of lower cost solutions to the Roman strategic dilemma.

The first alternative strategy would keep 2 pebbles in Rome, but only 1 in Constantinople. The 4th would deploy initially to Gaul. This covers one more node initially, improving deterrence, and reduces the cost of movement to Britain to 2. On the other hand, responding to a crisis on the frontier with the Persian Empire now costs 2. Total costs are 7 under this strategy. When win-win considerations are added, though, this strategy would leave 4 nodes beyond reach in the event of a second war, as opposed to the 1 (Britain) that would be sacrificed in the actual Constantinian strategy.

Obviously, political importance was attached to the forces deployed in and around Rome, and it would be hard to conceive of a strategy that failed to retain substantial forces there. Nevertheless, for analytical purposes, it is interesting to consider a second strategic approach, with two variants, in which Rome alone, then both Rome and Constantinople are neglected. In the first variant, 2 pebbles each are placed in Gaul and Constantinople. The cost is 1 to move to all nodes, except for North Africa, which has a cost of 3. Thus, the aggregate cost is 8, marginally better than the actual strategy employed. With regard to fighting two conflicts, this strategy leaves two nodes vulnerable, one more than under Constantine's strategy; unless the first conflict occurs in North Africa, after which response to second conflicts grows problematic. Thus, this strategy would likely require a willingness to sacrifice North Africa.

For example, a first war in Britain leaves Iberia and North Africa open after the initial Gaul-Britain move. Similarly, a war in Asia Minor leaves Egypt and North Africa beyond reach. Finally, a war in Egypt would result in uncovering Asia Minor and North Africa. The problem with the Gaul deployment is that it makes bridge building to reach the second conflict impossible (except if the first war is in Rome) when a bridge is required to move field forces to distant regions.

The most effective "non-Rome" option for coping with the abovementioned situation would be to keep 2 pebbles in Gaul, but to shift the 2 in Constantinople to Egypt. This reduces total costs to 6, a one-third savings over the historical strategy employed. However, the problem of covering the second conflict is double that of the Constantinian strategy. For example, a first war in Asia Minor leaves Constantinople and North Africa uncovered. If the first conflict is in the west, though, say Iberia or Britain, then only one node remains uncovered. Thus, this strategy would have reduced the overall costs of winning substantially, and only marginally worsened the empire's ability to respond to a second conflict. Of course, the dark political consequences of removing forces from the two capitals are hard to contemplate and would, undoubtedly, have been politically unacceptable.

With this last concern in mind, returning pebbles to Rome, aside from its political attractiveness, allows for introduction of the most efficient "one war" strategy. This consists of a hybrid of forward and depth defenses, with 1 pebble each in Britain and Asia Minor, and 2 in Rome. In this configuration, the overall cost of dealing with one war anywhere is 5. Unfortunately, the response to the first war leaves four nodes open that cannot be protected in the event of a second conflict. Adding 1 more pebble in Rome would solve this problem, but such an increase would have strained the empire greatly.

On balance, the Constantinian depth defense strategy forms the most attractive option. Its seemingly high cost in winning one war is an artifact of the cumbersome moves required to defend Britain, where this analysis implies deterrence would most likely fail. On the other hand, for purposes of coping with two wars, this strategy minimizes the vulnerable nodes (to one, Britain), a better result than any other deployment scheme. No historical record suggests that the Romans employed graphical analysis in their strategic planning; but it is interesting that they identified Britain as a particular defensive problem, leading them to the creation there of one of history's more ambitious efforts in fortification.

If the Romans demonstrated such refined strategic insight, then what accounts for the collapse of the empire? Ferrill (1986) argues convincingly that the fall of the empire resulted from a lessening of the military effectiveness of the legions. The move to depth defense caused a reshaping of the legionary forces to incorporate more mobile cavalry which, Ferrill argues, inadvertently debilitated the Roman infantry by sapping its numbers. Gibbon ([1776]1909, 322) contends that the fall of the empire came soon after Roman infantry discarded their body armor (so that they could move faster on the march).

Thus, Rome fell because its "pebbles" lost their value of "1." They increased mobility at the cost of fatally compromising their hitting and holding power. This problem does not appear to apply to the next, British, case; but it resonates with current debates about the appropriate "lightness or heaviness" that U.S. forces should possess in the post-Cold War world. In another respect, the Roman case also compares more closely with the United States than Britain, in that Rome combined land and sea power, while Britain remained essentially a maritime power, albeit one that could, when necessary strike powerfully on land. Finally, the British case will prove somewhat clouded, because of the presence of a rapidly emerging rival (exemplified by the German maritime threat). Rome in the 4th century faced a multitude of smaller, potential threats, much as the United States does in the immediate post-Cold War period.

The Pax Britannica

Like Rome, Britain enjoyed a period in which it was a sole "superpower." In 1816, a year after the fall of Napoleon, the Royal Navy possessed two-thirds of the capital ships *in the world*. It outnumbered the Russian fleet, in terms of warships of 60 guns or more, by 5:1; France by 4:1; and the United States by over 20:1. Additionally, Britain enjoyed almost equally favorable margins in smaller vessels such as frigates and gunboats (Modelski 1988). For comparative purposes, though, in terms of setting the number of "pebbles," only British capital ships are considered, as were only regular Roman legions in the previous case. Smaller vessels are analogous to the Roman auxiliaries, and equally vulnerable. In the words of First Sea Lord Jacky Fisher, any moderate-sized opponent could "lap them [all] up like an armadillo set loose on an ant-hill!" (Kennedy 1976, 216).

In addition to its overwhelming naval mastery in the immediate post-Napoleonic period, Britain also enjoyed control of three-fourths of world trade. However, the Pax Britannica itself, which ensured the freedom of the seas and fostered trade openness, spurred growth at such rates that Britain itself could not avert a tendency toward relative decline. By 1860, its share of world trade had fallen to 25%, by 1900 it was 17% (Kennedy 1976, 190). In terms of naval power, its share of global capital ships fell from nearly 70% in 1816 to 50% in 1860 and, in 1900, to under 40%.

Like the Roman legions, the capital ships of the Royal Navy, early on, deployed to the various perimeters of the empire, providing a robust forward defense. For example, in 1848, four-fifths of the warships of the Royal Navy were stationed outside the home islands (Kennedy 1976, 170). In terms of "pebbling," where six Roman legions comprised a force capable of dominating any given sector, the British Admiralty appeared to have followed a loose policy of amassing twenty-ship battle fleets during the age of sail, reducing this to eight in the era of steam propulsion and steel. These minimums needed for local dominance would give Britain an inventory of six "pebbles" in 1816, reducing to four by the turn of the 20th century. In this British case, the small professional army

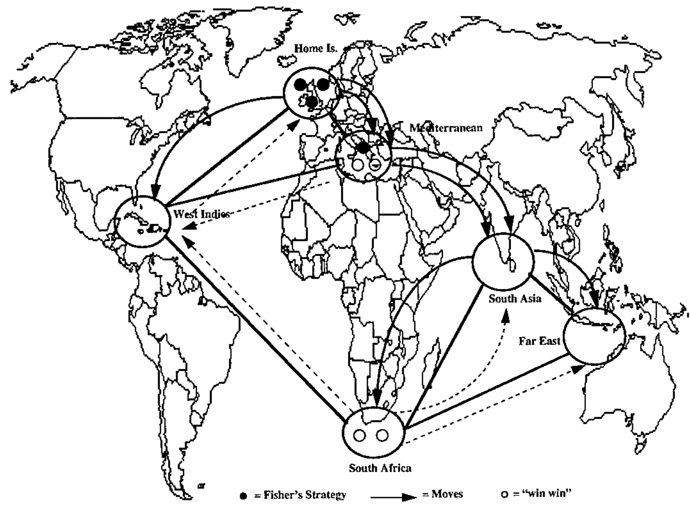

Figure 3. Strategic Schematic of the British Empire

is held constant, and is considered as a "projectile" fired by the Royal Navy into any given regional conflict; one, when properly supplied and supported, which consistently provided the empire with a high probability of success.

Figure 3 presents the British strategic schematic, with nodes at all key reaches of the empire, which has a complexity of 2. Early in the 19th century, the Royal Navy had the wherewithal to remain on station with dominant forces at each of the six key nodes of the empire. By 1900, though, down to four pebbles, small adjustments had been made. Instead of one pebble per node, two were kept in home waters, with one each in the Mediterranean and one in South Asian waters. This still had much of the appearance of a perimeter positional defense, or at least was no better than Diocletian's "shallow depth" strategy for the Roman legions. In 1905, though, Admiral Fisher, driven by his fear of dispersing his scarce resources in the face of rising German naval power, moved to a full depth defense. In schematic terms, he placed three pebbles in home waters, leaving one in the Mediterranean, and none elsewhere (Fisher 1919; Marder 1940; Kennedy 1976, 217).

Was Fisher right? Was his redeployment efficient? Optimal? The Fisher strategy of defense-in-depth could see to it that British forces arrived anywhere eventually. To achieve winning conditions against any one adversary, the "pebbling cost" of his approach amounts to 11, with 5 of this cost accounted for by movement to the Far East, 3 to reach the Cape of Good Hope and 2 to respond in South Asia. With regard to coping with a second conflict, Britain could reach any second war as long as the first one developed in South Asia. This would create a bridge which could then be employed to reach either the Cape or the Far East.

The high costs of the Fisher strategy, and the conditionality of the "win-win" capability encourage some application of graphical analysis in pursuit of more efficient strategies. The central problem to tackle in the British case is the great distance between Britain and the Far East. One solution consists of reducing the pebbles in the home islands to 2, and placing 2 in the Far East. This allows for a response time of 1 to any conflict, with an aggregate cost of 4. The cost is the same if the Far East forces are stationed in either South Asia or at the Cape of Good Hope. Alternately, 2 pebbles each in the Mediterranean and at the Cape, or in the West Indies and South Asia, also have aggregate costs of 4. These latter two cases have the additional benefit of creating win-win situations, as they permit a successful response to any second conflict that arises, at worst-case additional costs of 3.

Given the strategic imperative of balancing against the rising German threat, Britain would likely not have adopted either of the win-win strategies, as each requires weakening the defenses of the home islands. Given the incredible popularity of the "invasion scare" literature of this period, there can be no doubt of the domestic political constraints upon any effort to move the fleet to peripheral areas. However, it might have been possible to reduce the home fleet to 2 pebbles (from Fisher's 3). Then, with 1 in the Mediterranean and 1 in South Asia, a winning situation could be achieved at a total cost of 7, a 44% saving on the Fisher plan. Nevertheless, this scheme fails to achieve the conditions for a double win.

To summarize, graphical analysis points out that Britain could have achieved a double win, and reduced its single win costs by 80%, by moving its fleet units to peripheral areas. This finding suggests that, under some circumstances, defending forward, even when limited by straitened economic conditions, may prove superior to a pure depth defense. Aside from cost reductions, of course, this approach maintains the kind of forward presence needed to shore up deterrence. As the American case unfolds, this insight about deploying forward may have particular value, as the United States suffers nothing of the sort of great power rivalry, or vulnerability to invasion, that Britain confronted, or thought it did, a century ago.

Implications for the United States in the Post-Cold War World

Can this graphing methodology, along with insights from the foregoing historical cases, help to determine the appropriate size of and optimal deployment scheme for U.S. forces? Or, more simply put, how many pebbles are needed, and where should they be placed? These questions may be answered explicitly, though the issue of quantitative requirements depends upon the definition of the force size necessary to achieve a probable win in any regional conflict. How much is an American pebble? For Rome, it was six legions of regular forces. For Britain in the age of steam and steel, it was eight capital ships, their supports, and an expeditionary force. An American pebble, however, must be more multifaceted, comprising sea, air and ground forces.

Perhaps the best guidance to determining the specifics of an American force sufficient to win a regional conflict comes from the "bottom-up" study prepared by Les Aspin. In it, the former defense secretary argues first that, in order to win one regional conflict, the United States would have to maintain, at the upper level, standing forces of 5 divisions of ground forces, 10 air wings and 5 carrier battle groups (1993, 10). These figures include what is needed for standing treaty commitments (in Europe and Northeast Asia, principally) and for purposes of the rotation base (mostly in the continental United States). His analysis does not specify the amounts needed for the "win win" strategy, but implies that doubling the force is not quite necessary.

Accepting Aspin's approach, one may then conservatively estimate total force requirements of 10 divisions, 20 air wings and 10 carrier battle groups, an amount that comes very close to the revised "base force" projections with which his study concludes (1993, 17). In actuality, though, U.S. forces will likely have a few less air wings and at least two more carriers. Since each carrier services approximately one wing of attack aircraft, the net figures remain unchanged.

Extrapolating from Aspin's figures, one may now configure each U.S. pebble as composed of 3 divisions of ground forces, 3 carrier battle groups (including a Marine expeditionary force) and 5 air wings (approximately 375 aircraft). Reserves are not included in these figures, as their impact is felt most substantially in longer wars, given their need for mobilization and combat training.[5] Regional wars will remain the province of regular American forces, much as regular Roman legions bore the brunt of the empire's defensive and deterrent needs. As with the previous cases, this analysis also excludes allied forces for purposes of contingency planning.

The preceding calculations allot 4 pebbles to the United States.[6] Figure 4 represents the strategic schematic of the United States in the post-Cold War world, which has a complexity of 1. It substantially resembles the pentagonal example from Figure 1; but, because of the ability to move from the United States directly to either Europe or the Near East, this figure provides a somewhat easier set of solutions, and fractionally reduced complexity. Rather than recapitulate the analysis of the pentagonal example, the most

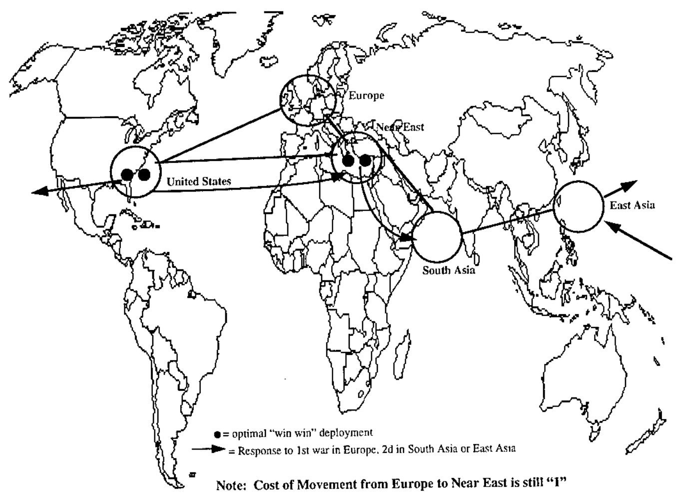

Figure 4. Strategic Schematic of The United States

relevant strategic options and costs can be easily displayed in Table 2.

For purposes of achieving a single win, strategy VII provides the least costly option, and also allows for rapid (one move) response to either of the two unoccupied nodes, Europe and the Near East. The implication for policy here is to de-emphasize Europe and the Mediterranean.[7] However, among multi-nodal configurations, only strategies II and XI provide a win-win option; and this approach creates, in the former instance, a powerful presence in the Levant whose implications, for the Balkans, the Maghreb and the rest of the Arab world, would

Table 2. U.S. Strategic Options

	Node					
Strategy	United States	Europe	Levant	South Asia	Far East	Cost, 1 win
I	2	2				4
II	2		2			3
III	2	1	1			4
IV	1	1	2			3
V	1	2	1			4
VI	1			1	2	4
VII	2			1	1	2
VIII	4					6
IX	3	1				4
X	1	3				4
XI	3				1	4
XII	3				1	5

Note: Only Strategies II, VIII and XI achieve "win win" conditions.

be profound. In the latter case, a much greater standing presence in the Muslim world is also implied. As both strategies call for increased presence in those areas where political pressures for "minimized presence" are greatest, they might prove difficult to pursue in practice.

In terms of deterrence, Strategy II would respond at a cost of 1 to any first war; but deterrence of a second conflict could be weakened, as two moves might be needed to respond in the latter case. For example, with 2 pebbles each in the United States and the Eastern Mediterranean, a war in Europe would necessitate moving 1 from either node. If forces came from the U.S., then responding to a second war in the Far East would require staging forces from the Eastern Mediterranean through the United States on their way to this war, at a cost of 2. If the initial response came from the forces in the Mediterranean, then a second war in South Asia would necessitate a response from the United States, through the Mediterranean, then on to the scene of the conflict.

It should also be noted that pulling U.S. forces home (VIII) raises response time substantially, to treble the cost of the most effective single-war strategy (VII), and double that of the only multi-nodal strategy that allows a "win win." However, an "all-U.S." configuration does allow a win-win situation, albeit at costs that could run as high as 3 to reach the second war if, for example, the first war were in Europe, and the second broke out in South Asia. This implies an even greater weakening of deterrence through adherence to a strict depth defense that would allow the initial overrun of peripheral areas.

Finally, if, for whatever reason, the United States were to shift to a one-war strategy, then it could achieve a win with only three pebbles, a 25% reduction *beyond* those cuts currently envisioned to reach base-force goals. This would, however, put the United States in a position from which it could not, given its resources, cope with a second conflict in a timely manner. Also, response to distant crises would be slower, weakening deterrence.

With regard to the insights provided by the historical examples, the key point is that both cases confirm the logical correctness of shifting to depth defenses under conditions of scarcity. However, the reduction in forward presence, coupled with the time needed to respond to distant crises, also showed that depth defense may vitiate deterrence stability. Thus, there exists a tension between efficient defense, employing an economy of force, and robust deterrence. Of course, this finding rests on the notion that successful deterrence generally depends upon the maintenance of a viable defensive force (as opposed to "flag-waving" detachments), either in the threatened region, or near enough so as to provide a rapid response. This formulation has received strong theoretical and empirical support in recent years, notably from Mearsheimer (1983), Huth and Russett (1984, 1988) and Huth (1988). Others (Jervis, Lebow and Stein, 1985; and Payne, 1992) have pointed out the consistent perceptual problems that aggressors have exhibited throughout history, reinforcing the point that robust deterrence may depend on having viable defensive capabilities in place, or nearby, in a crisis.

Finally, this formal analysis of the American strategic situation suggests the possibility of shifting deployments in Europe away from the central plains of Germany to the Mediterranean. Such a move improves response time to any South Asian crisis. It would also, no doubt, shore up deterrence against the spread of unrest from the Balkans, or against any sort of missile threats from the Maghreb. One policy implication might thus be to give very serious consideration to Albania's application for NATO membership. Given the apparent waning of the Russian threat, a southward shift of U.S. forces, strategically optimal from a graphing perspective, could take advantage of an opportunity to enhance security throughout the Mediterranean, from the Balearics to the Balkans.

CONCLUSION

Several insights have emerged from applying the graphing methodology described herein. Most significantly, this approach helps both in identifying optimal strategies and determining the minimum level of resources required for effective deterrence and defense. Also, the methodology can detect and then quantify the effects that reduced or increased force levels have on marginal costs. Finally, this study provides a verdict on the prospects for successful "win win" depth defense, confirming that the "base force minus" reductions which the U.S. military currently endures do not, of themselves, compromise its ability to fight and win two regional conflicts with near simultaneity. Further, if American strategy were to shift to a willingness to fight one war at a time, U.S. forces could reduce to even lower levels. In this case, though, deterrence could be substantially weakened, as the response time needed to reach most crises would lengthen considerably.

One should remain cautious regarding the applicability of formally- derived findings such as those generated in this study. While the mathematics of graphing may imply an ability to reduce forces sharply, thanks to optimized redeployments, the political reality of maintaining minimal standing forces is that considerable institutional opposition will likely arise. Indeed, one of the lessons of the Vietnam War for the American military was that overwhelming force should be applied whenever possible. Examples of this philosophy abound, from the massive expeditionary forces that descended upon one Cuban construction detachment in Grenada (as opposed to the losing "shoestring" forces that invaded Cuba in 1961 at the Bay of Pigs), to the preponderant forces that quickly overran the various militia-like "dignity battalions" of Noriega in Panama. Even the Iraqis, the strongest of America's recent adversaries in war, found themselves confronted by overwhelming air, sea and ground forces of the United States.[8]

The point here is that there may be organizational, bureaucratic political, or even prudent strategic reasons for wanting to have more forces than required by some theoretically-derived minimum level. After all, moving toward any minimum requirement entails risk. One can hardly quarrel with such "perturbing" factors, in terms of their existence. However, one may employ the arguments advanced in this study to determine "bottom line" requirements accurately. In this regard, the graphing methodology provides a value-neutral framework for analysis that may help to mitigate the natural tensions that arise between a desire for robust security and the need to operate under ever more constrained fiscal circumstances.

Finally, this methodology has generated the insight that marginal increases over bare-minimum force requirements can have very substantial effects in terms of improving coverage of key areas and response time in an international crisis. In the generic model (the "pentagon" of Figure 1), one pebble more than the minimum reduced costs of response by 50%. This means, in theory, that deterrence stability could be decisively enhanced with modestly larger forces. The implication for American defense policy may be that, even though the base force can achieve the "win win" grand strategy, its minimalist nature may weaken deterrence in crisis, leading to the outbreak of, and American involvement in, more wars. If this is true, then it behooves U.S. policymakers to contemplate the deterrent and stabilizing effects of having just one more "pebble."

ENDNOTES

1 Friedberg (1988), in his examination of Britain in the pre-World War I period, notes both some efforts to retrench, but also reflects on the terrible tension caused by "trying to continue to play the part of a world power without being willing to pay for the privilege" (p. 303).

2 For the purposes of this study, it is assumed that all nodes, or regions, are "created equal." That is, one pebble can win anywhere, even though the cost of moving one a great distance may be great, once there it performs as well as it would nearer to home. Much evidence supports the notion that the Roman legions fought at a relatively constant level of military effectiveness across a wide variety of regions. Similarly, the U.S. forces, that had been developed and trained for combat in Central Europe made a smooth transition to desert warfare in the war against Saddam Hussein.

3 The cost structure employed herein also captures the essence of the problem associated with the movement of expeditionary forces: the ability to move depends upon having rearward infrastructure. In U.S. practice, this notion of

the "rotation base" forms a central element in American force projection capabilities.

4 Similarly, while one may have allies, it is prudent (and a standard practice) in contingency planning to set military requirements on the basis of having to fight on occasion without militarily effective (e.g., the GCC states' armed forces in 1990) allies.

5 Two other assumptions underlay these calculations. First, it will remain necessary, for the foreseeable future, to move heavy forces by sea to any given region. Second, conventional war has not yet reached a stage at which American information and other high technology, included space-based weapons, have significantly lessened the need for large field forces.

6 The aggregate requirement for twelve divisions is met by combining the ten Army divisions with the three Marine divisions that will continue in existence. This leaves a slight overage.

7 It is assumed, for political reasons, that at least 1 pebble will have to remain in the continental United States and its environs.

8 Indeed, Aspin (1992, 29-34) argues forcefully that the Iraqis had considerably fewer troops in and around Kuwait than the half-million figure commonly assumed. The actual Iraqi order of battle could have had as few as 183,000 troops. Of course, U.S. air and naval mastery made the odds against the outnumbered Iraqis much worse.

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